Shaping your past - can otolith shape and structure identify dispersal histories in an amphidromous Galaxiid

Eimear Egan, Mike Hickford, John Quinn & David Schiel

Background

- Juvenile *Galaxias maculatus* are the basis of an important recreational fishery in New Zealand (Figure 1)
- Little understanding of the population dynamics during the marine dispersive phase
- Given the oceanographic patterns & latitudinal differences in SST we hypothesise that populations do not mix at large spatial scales
- Otolith shape is used as a population discrimination tool. Difference in morphology have been attributed to genetic and environmental factors inducing different growth rates between groups of fish
- We use this technique in conjunction with microstructure to characterise the population structure in three important fishery zones

Figure 1. Juvenile *Galaxias maculatus*

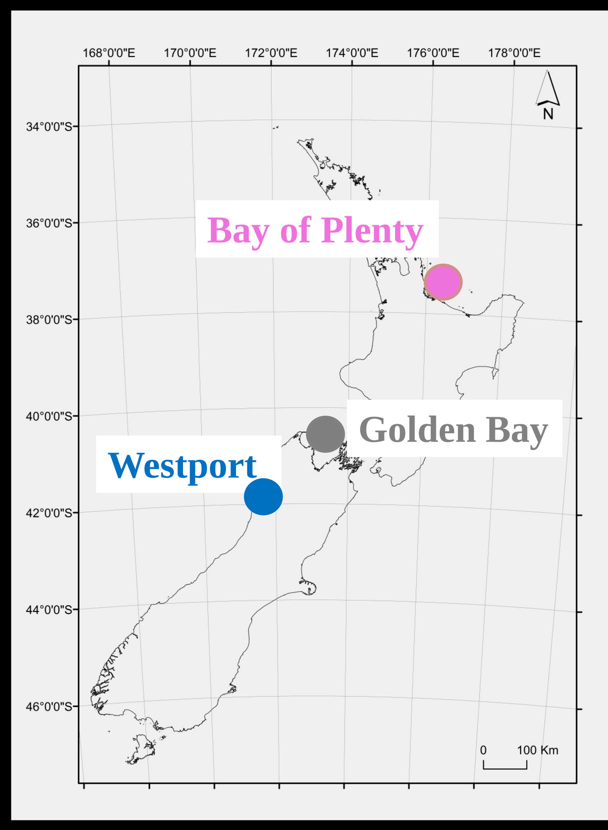
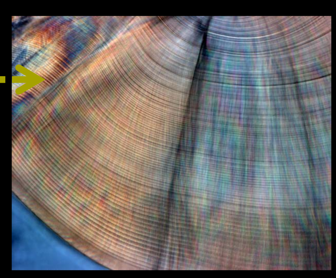


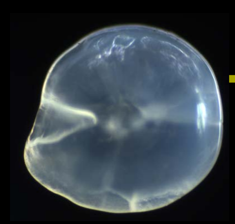
Figure 2. Sampling sites

Methods

1. Juveniles sampled (n=200) upon upstream migration from three regions (Figure 2)
2. Otoliths digitised(100x)
3. Otolith Morphology
4. Otolith **Microstructure**



- Increment width
- Pelagic larval duration



- Area
- Perimeter
- Length
- Width

Aspect ratio
Form factor
Circularity
Ellipticity
Roundness
Rectangularity

Shape indices

- Outline coordinates (x,y)
- Fourier analysis (Momocs in R)
- 10 harmonics = 99% reconstruction
- Harmonics standardised
- N= 37 harmonics coefficients

Elliptical Fourier harmonics

Analysis

- Morphology
  a) Shape indices size adjusted by common within group slope (ANCOVA, F= 1.237,df =12, p=.254). Fish length used as covariate , n=5 shape indices for analysis
  b) Univariate ANOVAS on shape indices and harmonics, Bonferroni corrected
  c) PCA shape (correlation) + harmonics (covariance), variable reduction, collinearity of variables
  d) Canonical analysis on combined Principal components
  e) Jack-knife validation to reclassify and measure effectiveness of otolith morphology to discriminate a-priori groups
- Microstructure
  a) Linear mixed effects modelling to reconstruct growth histories (lme4 in R)
  b) Increment width and age centred & ln transformed
  c) Fixed effects = Larval duration, Fish total length (mm), Age at increment formation & Population (ML)
  d) Random age slope & intercept for each fish (REML)

Results

Otolith morphology

- ANOVAS revealed significant differences between Bay of Plenty and Westport for harmonics C7, D3, D5 & D5. No significant difference evident for Golden Bay (Figure 2)
- Canonical analysis discriminated Bay of Plenty and Westport fish on first canonical axis (Chisq, p<.000), Figure 3. No discrimination on second axis
- Golden Bay overlaps both populations suggesting this region is a zone of mixing
- Mean reclassification success after Jack-knife validation ⟶ 55%
- High reclassification for Westport suggesting this population is a discrete entity (Table 1)

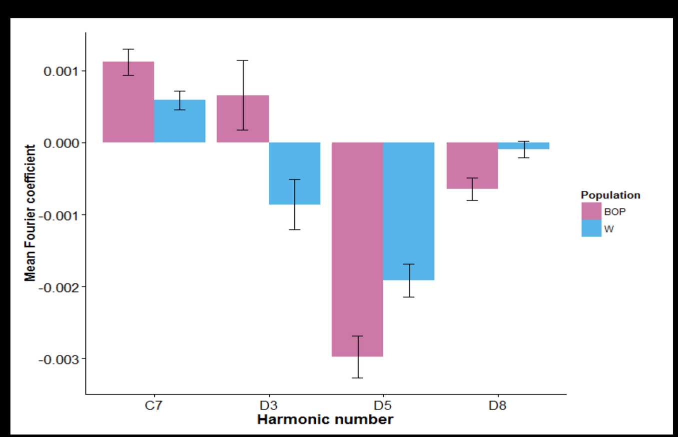


Figure 2. ANOVA of harmonics revealing significant differences

Population	Classification success (%)
Bay of Plenty	57%
Golden Bay	32%
Westport	74%

Table 1. Jack-knife classification results from Canonical analysis

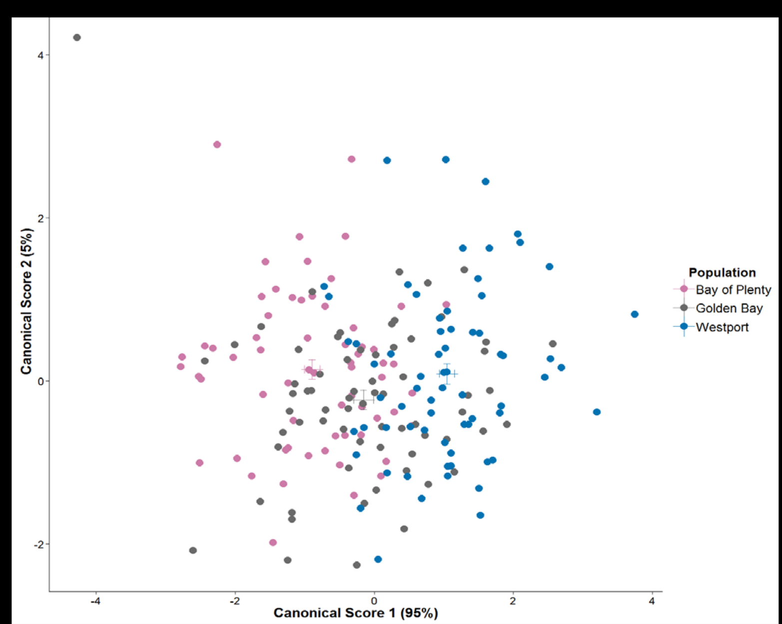


Figure 3. Ordination of populations on canonical axes. Crosses are mean ± s.e

Otolith microstructure

- Allometric increase in increment width with fish age
- Bay of Plenty fish achieved higher age dependent growth than Westport or Golden Bay (Figure 4)

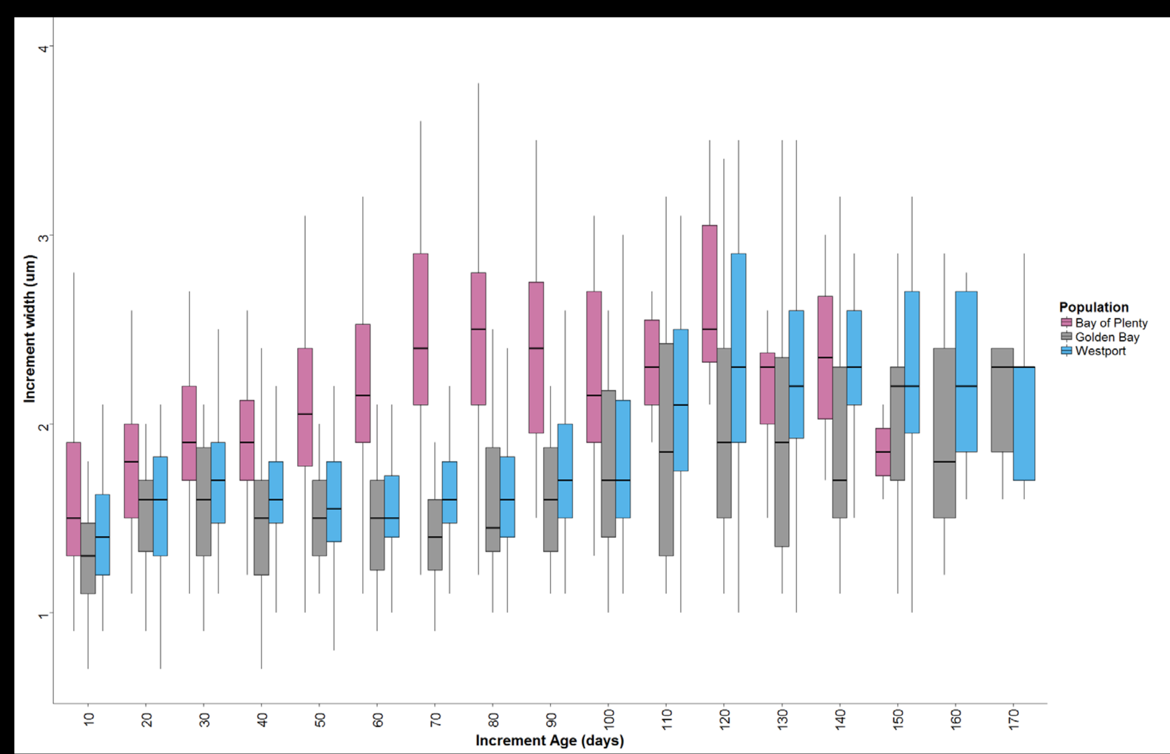


Figure 4. Boxplot of otolith increment widths for the three study populations indicating median and 1.5 IQR.

- Although no significant differences in growth between populations Golden Bay and Westport have shallower growth slopes (-.006 and -.003) respectively
- Inclusion of random age slope and intercept indicates individual differences in early growth become amplified during the first months of larval life

Conclusion

- The morphometric and microstructure analysis reveals high individual variability
- Results suggests that Bay of Plenty and Westport populations are unlikely to have experienced the same larval history. Preliminary results from the mixed effects models suggest that despite no significant difference in growth between populations the two southerly populations grow slower during the marine dispersive phase
- Westport fish may have achieved greater separation in the morphometric analysis due to the homogeneity of conditions on the west coast of New Zealand. Morphometric analysis may have failed to discriminate Golden Bay fish as this region appears to be a zone of high mixing. This is consistent with hydrodynamic patterns in the area whereby larvae may be distributed to this region by the Westland, Southland and D'Urville currents.
- These findings are important in the context of understanding this species population dynamics